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Design and Development of Apparatus to Measure Thermal Conductivity of Liquid

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Abstract - Thermal conductivity is the fundamental material property for characterizing the heat transfer. The measurement of thermal conductivity include the measurement of the heat flux and temperature difference. This study aims to design, fabricate and development a reliable instrument to measure the thermal conductivity. The apparatus is completely different form of thermal conductivity apparatus which has been widely applied in normal laboratory. A literature survey concerning available experiment technique for thermal conductivity measurement was conducted. The level of reliability that based on the accuracy and consistent will be proven by comparing the experimental value with theoretical value. The results obtained certified the aim of work which was to develop the thermal conductivity measurement apparatus suitable for data collection and experimental experience in economic way.

Key Words: Thermal conductivity, heat flux

1.INTRODUCTION

Heat is form of energy that can be transferred from one system to another system. Heat only can be transferred if system have temperature difference. Heat in generally can be transferred in three different modes including conduction, convection and radiation. The thermal conductivity of liquids is one of the most important transport properties in heat transfer through fluid. Accurate measurements of thermal conductivity are of considerable difficult. There are a number of presently existing methods to measure thermal conductivity of liquid. Each of these is suitable for a limited range of materials, depending on the thermal properties and the medium temperature. In steady-state techniques, the radial heat flow method has proven to be very successful in measurements of thermal conductivity. In radial system, heat flows radially away from a heater towards a heat sink, and thermal conductivity can be calculated from the temperature gradient inside the apparatus. In all cases the apparatus consists of an electrically heated wire or cylinder placed at the central axis inside a hollow cylinder. The cylinder is filled with test sample and is typically liquid cooled. When steady state is reached, by using standard formulae and thermocouple records, thermal conductivity can be calculated.

2. OBJECTIVE

Nowadays, various of methods to measure thermal conductivity such as hot-wired method, guarded hot plate method, 3w technique, the steady state technique, axial flow methods, radial flow method and etcetera.

The objective of this study are to design, fabricate and develop a thermal conductivity measurement apparatus for liquid. The principal method of measuring thermal conductivity is Fourier law.

To quantify the heat transfer process for heat conduction, the rate equation Fourier's Law is used,

Fourier's Law -

$Q = -k\ \partial T\ /\partial x.$

Where,

The heat flux, Q [W/m2], is the heat transfer per unit area.

$\partial T/\partial x$ [W/m] is the temperature gradient

k is the transport property known as the thermal conductivity [W/ (m*K)].

3.MATERIALS AND METHODS

The components used in this experiment are Copper pyramid, Silver Box, Temperature sensor with display, Pencil Heater, Wooden Block, PVC Insulation Tape.

An apparatus is designed and fabricated to measure the effective thermal conductivity of liquids. The apparatus is completely different form of thermal conductivity apparatus which has been widely applied in normal laboratory. It is designed in horizontal manner.

The liquid sample is placed in hollow silver box and two pyramid are attached to the two sides of silver box which are facing each other. The pencil heater is placed at the outer surface of one of the pyramid. The temperature sensors are placed between silver box and copper pyramid. With the help of temperature sensor two temperatures T1 & T2 are measured. And by using this data and with the help of thermal conductivity formula the thermal conductivity of liquid is calculated.

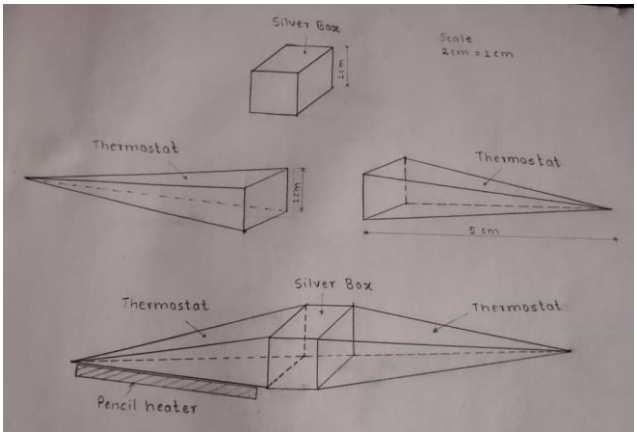

Figure 1: 2D design of experimental setup

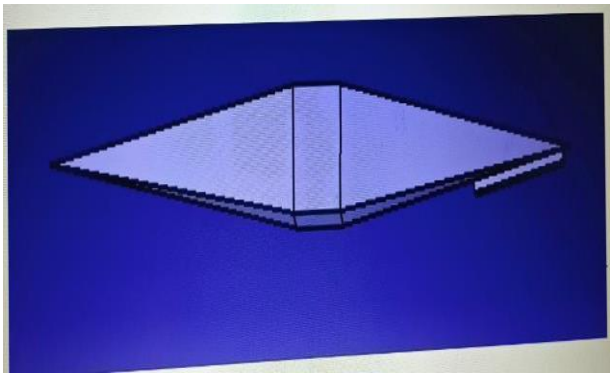

FIGURE2: 3D DESIGN OF EXPERIMENTAL SETUP

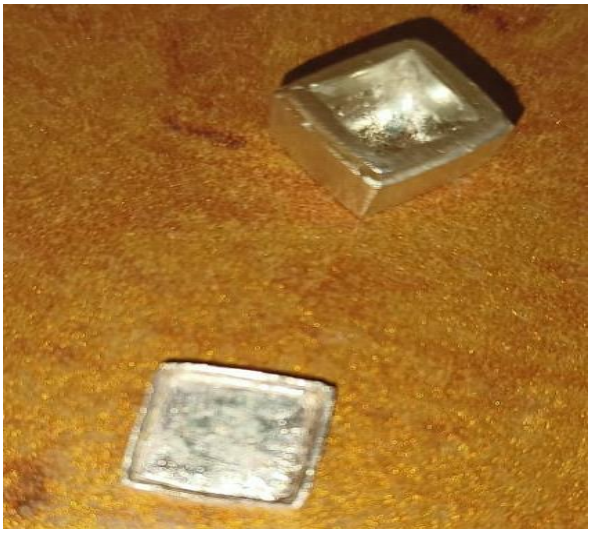

Figure3: Silver Box

A silver box is a cube having dimensions 1 cm. It is hollow from inside. It is used for storing liquid which we are using for this experiment. We used silver box to store liquids because it is an excellent conductor of heat. It also have the high melting point. By referring the design data book, we selected the dimensions for silver box 1*1*1cm.

4 COMPONENTS

4.1COPPRER PYRAMID

It is in a shape of pyramid having dimensions, width is 1 cm and the height is 5 cm. These Pyramid are made from copper. These Pyramid are attached to the silver box. The dimension we selected for copper pyramid is by using the design data book. We made copper pyramid of dimension 1*5cm from copper rod of dimension 1*5cm in workshop by using bench

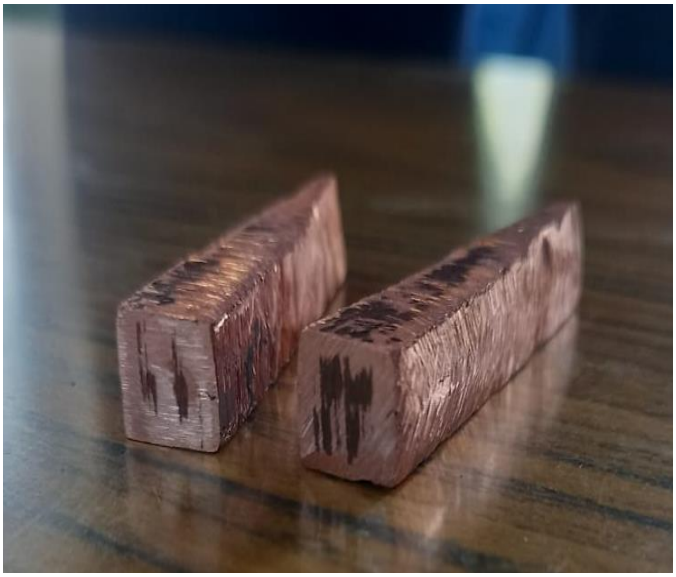

FIGURE4: COPPER PYRAMID

4.3. PENCIL HEATER

A pencil heater is a cylindrical tubular heating device that provides concise and precise heating for various forms of materials, machinery, and equipment. Unlike an immersion heater, a pencil heater is inserted into a hole in the item to be heated to furnish internal radiant heat. They are used in a wide range of manufacturing processes for providing precisely directed localized heat. The capacity of pencil heater which we used in the experiment is 25 W.

Pencil heaters are easy to install and provide an even heat pattern with watt density to fit the needs of the application. To facilitate installation, heaters have a slightly smaller diameter than the diameter of the hole into which they are installed to provide a snug tight fit.

4.4. THERMOCOUPLE

A thermocouple is a device used to measure temperature. This can be air temperature, liquid temperature or the temperature of solid matter. There are different types of thermocouple available and they each use different technologies and principles to take the temperature measurement. Wires attach to thermocouple are going to place between silver box and copper pyramids.

5. LIQUIDS

5.1 WATER

Water is a colorless and tasteless liquid. Water is an excellent solvent. Water has high heat capacity. It takes lot of energy to raise the temperature of a certain amount of water by a degree, so water helps with regulating temperature of environment.

5.2 COCONUT OIL

Coconut is a colorless liquid with a distinct taste and odor. Its boiling point is 177^0 C and its density is 0.9259 g/cm^3.

5.3 ENGINE OIL

Engine oil has density between 700 and 950 kg/m^3. The boiling point is around 300^{0}C.

5.4 VINEGAR

Vinegar is an aqueous solution of acetic acid and trace compounds that may include flavouring. Vinegar typically contains 5-8% acetic acid by volume.

Table1: standard value of thermal conductivity of liquid

Sr.No.	Liquids	Standard value of thermal conductivity (W/m.k)	Reference for standard value of thermal conductivity
1.	Water	0.0609	Fundamentals of Engineering Heat and Mass transfer by R. C. Sachdev.
2.	Coconut Oil	0.180	Fundamentals of Engineering Heat and Mass transfer by R. C. Sachdev.
3.	Engine oil (Castrol Edge SEA 5W-30)	0.145	www.engineeringtoolbox .com
4.	Vinegar	0.193	Fundamentals of Engineering Heat and Mass transfer by R. C. Sachdev.

6.EXPERIMENT PROCEDURE

1.First we set up the experimental set up.
2. Then we added sample liquids in a silver box.
3.By using the pencil heater heat supplied to silver box which is place between two copper pyramid.
4.The thermocouples are used for taking temperature. Then t_1 and t_2 are note down.
5.The temperature is display on digital displayer.
6.When we get temperature, by using given formula we calculated the thermal conductivity of sample liquids.
7. After getting experimental value, we compared it with the standard value.

6. OBSERVATION TABLE

Sr.No.	Liquids	Initial Temperature, t_1 (^{0}C)	Final Temperature, t_2 (^{0}C)
1.	Water	40	43
2.	Coconut Oil	39	49
3.	Engine Oil (Castrol Edge SEA 5W-30)	40	49
4.	Vinegar	53	59

TABLE2: OBSERVATION TABLE

8. CALCULATIONS

[Fundamentals of Engineering Heat and Mass transfer by R. C. Sachdev] :

Sample Calculations-

Formula –

$Q = -K.A.dt/dx$

Given –

$Q = 25$ W,

$dx = 0.05$ m.

Water –

Initial Temperature (t_1) = 40 ^{0}C = 313.15 K
Final Temperature (t_2) = 43 ^{0}C = 316.15 K
By using above formula,
K = 25*0.05/ (316.15-313.15)
K = 0.678 W/m.K

Coconut Oil –

Initial Temperature (t_1) = 39 ^{0}C = 312.15 K
Final Temperature (t_2) = 49 ^{0}C = 322.15 K
By using above formula,
K = 25*0.05/ (322.15-312.15)
K = 0.1785 W/m.K

Engine Oil–

Initial Temperature (t_1) = 40 ^{0}C = 313.15 K
Final Temperature (t_2) = 49 ^{0}C = 322.15 K
By using above formula,
K = 25*0.05/ (322.15-313.1
K = 0.138 W/m.K

Vinegar –

Initial Temperature (t_1) = 53 ^{0}C = 326.15 K
Final Temperature (t_2) = 59 ^{0}C = 332.15 K
By using above formula,
K = 25*0.05/ (332.15-326.15)
K = 0.2001 W/m.K

9 RESULT

Sr.No.	Liquids	Experimental value(W/m.k)	Standard Value(W/m.k)	Error
1.	Water	0.678	0.609	0.069
2.	Coconut Oil	0.178	0.180	0.002
3.	Engine Oil (Castrol Edge SEA 5W-30)	0.138	0.145	0.007
4.	Vinegar	0.200	0.193	0.007

Table3: Result Table

9. CONCLUSIONS

It measured approximate thermal conductivity of different liquids. To analyse the difference between standard value of Thermal conductivity of liquid and experimental value of thermal conductivity. The designed system for the measurement of thermal conductivity of liquid was applied to water as the test specimen. The results obtained highlight an interesting point that for low viscous liquids like water, distilled water thermal conductivity increases with increasing the temperature which is the unique property of the water. It also measured the thermal conductivity of various liquids such as coconut oil, engine oil, vinegar.

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